THE WAVERLYAN PERIOD OF TENNESSEE.

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INTRODUCTION.

Of late years much valuable information has been published concerning the lower part of the Subcarboniferous or Mississippian strata of the United States, so that to-day we know their history in considerable detail. Weller's various faunal and stratigraphic studies, relating chiefly to the Kinderhook of Illinois, Iowa, and Missouri, have furnished a foundation for the comparison of these strata in other states. In Ohio, Indiana, and Kentucky the stratigraphic succession is now fairly well known, but the correlations are in some instances doubtful, and the faunas particularly require much more study. In Tennessee a considerable thickness of early Mississippian rocks is present, but here little has been published on their stratigraphy and less on their faunas. The object of the present article is mainly to present a short account of these strata in Tennessee to supplement the paper by Mr. Frank Springer on "The Crinoid Fauna of the Knobstone Formation," published elsewhere in this volume. Mr. Springer has briefly summed up the results of Safford's work upon these rocks, but a more complete account is given below.

THE SILICEOUS GROUP OF TENNESSEE.

The Subcarboniferous rocks of Tennessee were divided by Safford into a lower Siliceous group and an upper Mountain limestone. The latter formation is not discussed in this paper; indeed, the scope of the present article is limited to the lower part of the Siliceous group.

Although the term "siliceous stratum" originated with Doctor Troost and was employed by him in his reports, the first description of these strata is by Safford in an article on "The Silurian Basin of Middle Tennessee, with Notices of the Strata surrounding it,"[1] where he divides the Paleozoic rocks of middle Tennessee underlying the Pentremital limestone into five sections. The fifth section, included

[1] Amer. Journ. Sci., ser. 2, vol. 12, 1851, pp. 352-361.

between the Black slate and Pentremital limestone, was called the Siliceous group. This group was subdivided in ascending order into the Siliceous beds and the Cherty limestone. The lower member, the true Siliceous beds, about 200 feet thick in the northern part of the state, consists of a fine-grained, siliceous, light blue, rather unfossiliferous limestone, which, upon weathering, leaves a light yellow to brown soil strewn with chert fragments. The cherty limestone proper differed "in being a true limestone affording a brick-red soil, in the character of its interbedded [flint] masses and in being much more fossiliferous." A species of *Lithostrotion* (*Lonsdalia canadensis*) was registered as one of the fossils.

In 1856 [1] Safford described the same strata under the same name, giving little additional information regarding the rocks.

In his well-known classic work, "Geology of Tennessee," 1869, Safford gives an excellent description of the Siliceous group, dividing it into the "Lower, or Protean bed," and the "Lithostrotion Coral bed." The Lithostrotion bed is characterized everywhere by *L. canadense*, and Safford correlates it with the St. Louis limestone. The lower or Protean member is said to be "in general equivalent to the divisions of the Lower Carboniferous limestone lying below the St. Louis limestone. It is, perhaps, more especially the equivalent of the Keokuk limestone; it contains, however, some Burlington forms." As Mr. Springer has indicated, the fact that most of the Lower Siliceous fossils listed by Safford are Keokuk species outside of Tennessee, has led to the correlation of these beds almost invariably with the Keokuk. This opinion is indicated in the "Table of Geological Equivalents" (by A. Winchell), on page 364 of the "Geology of Tennessee," where the Lower Siliceous is correlated with the Keokuk limestone of Iowa and Missouri, and with the Keokuk and Knobstone of Kentucky, while the Burlington and underlying Subcarboniferous strata are indicated as wanting in Tennessee.

Safford and Killibrew use the term Barren group instead of Protean bed for these strata in 1874 in their "Resources of Tennessee." Later, in their textbook "The Elements of the Geology of Tennessee," published in 1900, they abandon both the names Siliceous group and Barren group, substituting for these, respectively, St. Louis limestone and Tullahoma limestone, and introducing the new term Maury green shale for the basal member of the series in Maury County.

The next work upon the subject, so far as it relates to Tennessee, is by Hayes and Ulrich,[2] who adopt the names Tullahoma formation and St. Louis limestone, but include and map the Maury green shale with the Chattanooga black shale. In the Tullahoma formation they describe a lower calcareous shale member and state that it is fre-

[1] Geological Resources in the State of Tennessee, First Report, p. 159.

[2] Columbia Folio, Tennessee. U. S. Geol. Surv., Folio No. 95, 1903.

quently absent. This shale contains undescribed ostracods indicative of early Mississippian age. Above this comes the usual siliceous limestone with few fossils. In their correlation table the Tullahoma is made the equivalent of the Kinderhook, Burlington, and Keokuk of the generalized time scale.

The most recent discussion of these strata is contained in the paper entitled "Types of Sedimentary Overlap," by Dr. A. W. Grabau.[1] The portion of this paper devoted to the Tennessee Subcarboniferous is apparently based upon the literature alone, for this author writes:

> The Fort Payne chert is very fossiliferous, and is the "siliceous group" of Safford, which he divided into a lower, or Protean (Lauderdale, McCalley), and upper, or Lithostrotion (Tuscumbia, McCalley). Ulrich makes the Tullahoma of central Tennessee and the Fort Payne of eastern Tennessee equivalent, and correlates both with the Kinderhook and Osage of the Mississippi Valley. There is here an inconsistency, for the upper part of the Fort Payne (Tuscumbia) is clearly of lower Saint Louis age, as shown by the abundance of *Lithostrotion canadense* (=*L. mamillare*).

Taking up these statements in order, it may be said that, aside from dismembered crinoid columns, recognizable fossils in the Fort Payne are exceedingly rare. The Fort Payne is not the equivalent of the Siliceous group of Safford, because it does not contain the St. Louis limestone at its top. There is not an abundance of *Lithostrotion canadense* in the upper part of the Fort Payne. This characteristic St. Louis fossil is found only in the lower beds of the overlying Bangor limestone. Taking for example the McMinnville folio from which Grabau takes some of his statements, one acquainted with the area can easily make out the geological equivalents. Here the Fort Payne chert is described as a cherty limestone and heavy beds of chert, giving rise to a white, siliceous soil, and forming the barrens of the Highland rim. The overlying Bangor limestone has at its base a blue limestone member with nodular chert, weathering into a red, slightly cherty soil. It is in this latter red soil only that the characteristic St. Louis fossils are found.

The Lauderdale and Tuscumbia formations do not fall within the scope of the present paper, and need not be mentioned further, except to state that, as the names are of later date than the formations here discussed, they will in all probability be found to be superfluous.

The above notes include all of the more important references to the Lower or Protean member of the Siliceous group in Tennessee. In the discussion of the geology of neighboring states the terms Siliceous, Tullahoma, and other names have been frequently employed, but they need not be referred to at present, with one exception. This is the Fort Payne chert, a term proposed by Hayes [2] for practically the same strata in the southern Appalachian Valley. It is

[1] Bull. Geol. Soc. America, vol. 17, 1906, pp. 567–636.

[2] Idem, vol. 2, 1890, p. 143.

employed by the same author also in the McMinnville folio covering a part of the eastern rim of the Central Basin.

The Fort Payne chert seems to agree exactly with the Tullahoma of Safford and Killibrew, as founded on exposures of the formation in the eastern rim of the Central Basin. However, they used the name Tullahoma also for all the beds between the Maury green shale and the St. Louis limestone along the western edge of the basin, thus including the Kinderhook shale, which is there locally developed beneath the cherty beds. Hayes and Ulrich adopted the term in the latter sense in the Columbia folio. From the foregoing it will be noted that there is no Tennessee term which includes all of the Subcarboniferous rocks, including the Chattanooga shale, forming the subject of the present paper, namely, those underlying the Lithostrotion or St. Louis limestone. Safford's subdivision "Protean member" comes nearer to covering this interval than any other, but this term has no geographical significance. As the St. Louis limestone of Tennessee occasionally contains a Warsaw fauna in its basal layers, the underlying Subcarboniferous rocks will fall into the Mississippian Period, as recently emended by Schuchert.[1] Newberry's Waverly group covers the same interval, and I have used this term in the title of my paper, first, because it has priority, and, second, because it requires no revision of boundaries as is necessitated by Schuchert's proposed restriction of the term Mississippian.

It is true that Newberry was not the author of the term Waverly, but I think it will be conceded that his writings form the most valuable contributions to the literature of the subject. By reference to Weeks's "North American Geologic Formation Names,"[2] it will be noted that the term Waverly was first applied by Mather, in 1838, to the Subcarboniferous sandstone series in Ohio. Then Owen used the term on two occasions in the early Indiana reports, regarding the Knobstone group of that state as a synonym. The first definite limits to the group were those given by the next writer upon the subject, Newberry, who, in his "Report of Progress of the Ohio Geological Survey for 1869," included the Cuyahoga shale, Berea grit, Bedford shale, and Cleveland shale as members of the Waverly group. In all of Newberry's subsequent works, and, indeed, that of most subsequent writers upon the subject, these same divisions are recognized in the Waverly group, although at times the separate divisions have been designated as Waverly sandstone, Waverly shale, or Waverly black slate. Excluding the Chattanooga shale, the term Waverlyan is employed as a series term by Ulrich[3] to include deposits of Kinderhook, Burlington, and Keokuk age.

[1] Paleogeography of North America, Bull. Geol. Soc. Amer., vol. 20, 1910, p. 547.

[2] Bull. 191, U. S. Geol. Surv., 1902, p. 414.

[3] Prof. Paper, U. S. Geol. Surv., No. 36, 1905, p. 24.

THE WAVERLYAN PERIOD.

In the following pages I have included the Chattanooga shale, with its initial deposit, the Hardin sandstone, as a part of the Waverlyan. As mentioned before, Newberry, in all of his works on the Waverly, considered the Cleveland shale as its lowest member. In his Ohio report, published in 1874, he mentioned fish remains and large numbers of conodonts as its most abundant fossils, these being described later in volume 2 of the "Paleontology of Ohio." A thin, impure limestone containing *Syringothyris typa*, *Macrodon hamiltonae*, and other Waverly fossils, inaugurated the Cleveland shale and separated it from the underlying Erie (now Chagrin) shale holding *Spirifer disjunctus* and other Chemung fossils. Accepting Newberry's classification of the Cleveland shale as the basal member of the Waverly, the present stratigraphic divisions of this series in Ohio are as follows:

Divisions of Waverlyan in Ohio.

7. Logan formation, mainly sandstone.
6. Black-Hand formation, sandstones, often coarse and conglomeratic.
5. Cuyahoga formation, clay shales and sandstones.
4. Sunbury formation, fissile black shale.
3. Berea sandstone.
2. Bedford shale, locally with sandstone.
1. Cleveland black shale.

Foerste, in his article on The Bedford Fauna at Indian Fields and Irvine, Kentucky,[1] correlates the Logan formation with the Keokuk by two errors, which, curiously enough, nullify each other and leave the correlation probably correct. His statement is as follows:

> In 1888 Mr. E. O. Ulrich, in the fourth volume of the Bulletin of Denison University, identified from the Upper Waverly of Ohio sixteen species of bryozoans which occur also in the Keokuk of Kentucky, Illinois, and Iowa. Of these, eight are found at Kings Mountain, Kentucky, in strata identified by Ulrich as Keokuk, and two other species are closely related to forms found at that locality. From this it is evident that the upper Waverly, now known as the Logan formation, is closely related to the strata exposed at Kings Mountain, and that both are approximately equivalent to the Keokuk of the Mississippi Valley.

However, the bryozoans described by Ulrich were derived from the upper part of the Cuyahoga formation and not from the Logan. Again, the Kings Mountain strata are not of Keokuk age but belong to the typical Knobstone shale.

In an article entitled "The Waverly Formations of East-Central Kentucky,"[2] Morse and Foerste show that the Bedford and Berea formations thin rapidly southwestward from the Ohio River, in fact,

[1] The Ohio Naturalist, vol. 9, No. 7, May, 1909.

[2] Journal of Geology, vol. 17, No. 2, 1909.

become so thin that the Sunbury, Bedford, and the underlying black shales seem to become a unit. In Kentucky then, quoting these authors, "The Ohio black shale of the Kentucky reports or the Chattanooga shale of U. S. reports, south of Petersville, is not of Devonian age alone but of Devonian and Carboniferous; that is, is composed of both the Ohio and Sunbury shales, and a thin zone representing the Bedford and Berea."

In the Richmond and other folios of east central Kentucky, the U. S. Geological Survey maps the clay shales and sandstones between the Newman limestone, as identified in this area (St. Louis and Chester), above, and the Chattanooga shale below, as the Waverly formation, giving the Waverly the same limits as in Ohio, save that the lower black shale divisions (Cleveland, Bedford, and Sunbury) with possibly a black shale of Devonian age, are mapped as a unit under the name of Chattanooga shale.

In central Tennessee the Chattanooga black shale with the underlying Hardin sandstone undoubtedly represents the deposits of the first submergence following the Devonian emergence. Whenever present the Hardin sandstone almost invariably contains worn, silicified fossils of Ordovician, Silurian, and Devonian age, and in addition shows specimens of many of the fish teeth and conodonts described from typical Cleveland shale in volume 2 of the "Paleontology of Ohio." This same fauna occurs in the typical Chattanooga shale at many Tennessee localities. At Mount Pleasant, Tennessee, specimens of the conodonts especially are so numerous that some of the layers at the base of the black shale here are composed almost entirely of these fossils alone. At Bakers, Tennessee, as indicated in the Bakers-Ridgetop section presented on a later page, these same conodonts and fish teeth are present in both the basal part of the typical black shale and in the Hardin sandstone member of the Chattanooga. The most southern locality where this fauna has been found is near Huntsville, Alabama, where the basal layers of the Chattanooga are crowded with the same conodonts. Although the division line between the Devonian and Carboniferous in Ohio is still in doubt, as indicated in Professor Prosser's paper "Revised Nomenclature of the Ohio Geological Formations," [1] it seems to me that there is sufficient evidence published to justify the regarding of the Chattanooga shale of central Tennessee as basal Waverlyan. That this black shale in central Tennessee is correctly correlated with the Chattanooga shale of the Appalachian Valley is another question, but I think such a correlation can be proven.

With the exception of the Rockwood formation of Silurian age, the stratigraphic relations at Chattanooga, Tennessee, the type locality of this shale, are precisely the same as along the eastern rim

[1] Geol. Surv. Ohio, Bull. No. 7, 1905, pp. 2, 17-21.

of the Central Basin. East and northeast of this Chattanooga band of outcrop, a similar black shale, but of undoubted Devonian age, has been mapped as the Chattanooga shale. This shale in central Tennessee will, therefore, according to the present classification, be placed as the first formation of the Waverlyan. The remaining Waverlyan formations of Tennessee form more especially the subject-matter of the present article.

WAVERLYAN SECTIONS IN TENNESSEE.

The usual section of Waverlyan rocks in Tennessee is quite simple. Along the eastern side of the Nashville dome the section given in the McMinnville folio of the U. S. Geological Survey is quite typical. In fact, in a study of hundreds of exposures I have seen little deviation from it. This section, with the formations listed according to present-day nomenclature, is as follows:

Geologic section of Waverlyan, McMinnville folio.

	Feet.
Bangor limestone (of St. Louis and Chester age)	———
Waverlyan:	
Fort Payne chert—	
Siliceous limestone with heavy beds of chert at the base	150–225
Maury green shale—	
Light blue to green shale holding glauconite locally and usually containing a layer of phosphatic concretions	0–2
Chattanooga black shale—	
Carbonaceous fissile shale	10–30
Ordovician limestone (usually of Trenton age)	———

At a locality near Woodbury in Cannon County, just a few miles west of the McMinnville quadrangle, Safford has recorded the typical Keokuk fossil *Agaricocrinus americanus*.[1] I have examined this and many other similar sections in the Woodbury quadrangle and find that the stratigraphic succession is identical with the McMinnville section given above. The crinoids come from the basal part of the Fort Payne chert, and as the lowest layers of the overlying Bangor limestone contain *Lonsdalia canadense*, the whole of the Fort Payne chert falls within the Keokuk of the general time scale. The Chattanooga black shale and the Maury green shale afforded no fossils, but lithologically they are identical with the formations so named in the following sections. Tullahoma, the type-locality of the Tullahoma chert formation of Safford and Killibrew, is but a few miles to the south. Here essentially the same section is presented and the Tullahoma formation at its type-locality is, from all the evidence so far as known, likewise of Keokuk age. The Fort Payne chert at its type-locality in northern Alabama does not include the St. Louis at its top nor does it contain the Kinderhook shales at its base. It is, therefore, the same as the Tullahoma, and the latter term is discarded in favor of the former on the ground of priority.

[1] Geology of Tennessee, 1869, p. 342.

As previously stated, Safford and Killibrew and Hayes and Ulrich referred to the Tullahoma certain underlying shales which are locally developed along the northern and western sides of the dome. As these shales represent a distinct group—the Kinderhook—the new name Ridgetop shale is here proposed. An excellent development of the Ridgetop shale is seen in the section about to be described, from which the name is taken.

Geologic section along Louisville and Nashville Railroad, from Bakers to Ridgetop, Tenn.

	Feet.
Tennesseean:	
St. Louis limestone—	
Massive gray to blue limestone weathering into the characteristic angular, rather solid chert and red soil, with an occasional specimen of *Lonsdalia canadense* (top of hill)	——
Waverlyan:	
Fort Payne chert (Keokuk)—	
Massive to thin bedded, dark gray and drab, siliceous, practically unfossiliferous limestone weathering into a yellow, barren soil full of small plates of chert. These layers rest unconformably upon the underlying shales	100+
Ridgetop shale (Kinderhook)—	
(*i*) Light blue to green clay shale holding numerous ostracods and bryozoans	15–20
(*h*) Arenaceous shales with bands of porous chert, yielding silicified fossils	2
(*g*) Light blue to green shale with same fossils as second bed above.	36
(*f*) Unfossiliferous blue shales passing upward into light blue and green shales of bed above	4
(*e*) Thin bedded argillaceous limestone and compact dark shales with numerous fossils	5
(*d*) Dark, compact clay shale with few fossils	15
(*c*) Fine grained argillaceous sandstone weathering red and forming a conspicuous line in the section	1
(*b*) Light blue to green unfossiliferous shale	20
(*a*) Sandy, unfossiliferous chert	1
Maury green shale—	
Unfossiliferous green shale	1–2
Green shale containing phosphatic nodules	½–1½
Chattanooga shale—	
Carbonaceous black fissile shale containing numerous Cleveland shale conodonts and fish teeth in the lower beds	30
Hardin sandstone member—	
Iron stained conglomeritic sandstone composed mainly of chert and fragments of silicified fossils from older formations, resting upon the eroded top of the underlying Louisville limestone. Fish teeth and conodonts of Cleveland shale age are associated with the fossils of greater age	0–2 in.
Silurian-Niagaran:	
Louisville (Bledsoe) limestone—	
Massive, dolomitic, unfossiliferous limestone	0–17
Waldron (Newsom) shale	——

The town of Ridgetop is situated upon the lower part of the St. Louis limestone. Between the top of the ridge and the railroad station the full thickness of the usual Fort Payne is shown, while along the railroad near the station the uppermost beds of the Ridgetop shales are encountered. The latter are abundantly fossiliferous and contain besides numerous bryozoans and ostracods of known Kinderhook age, specimens of the species long ago described and listed by Prof. A. Winchell as of Marshall or Kinderhook age.[1] This fauna is not discussed in detail here, since it requires much more study before it can be listed and employed in exact correlation with Kinderhook formations in the Mississippi Valley.

The Maury green shale and the Chattanooga shale, with its Hardin sandstone member, show no unusual features in this section, and need no lengthy description. The Hardin sandstone is simply the physical representation of the unconformable relations of the Chattanooga shale, as evidenced by its conglomeritic nature. The Maury green shale is likewise conglomeritic. A similar phosphatic green shale almost invariably follows the Chattanooga shale at many localities.

In many sections the Maury green shale is succeeded by light blue to green shales bearing the Kinderhook fauna mentioned by Winchell, but in the present section the lowest beds assigned to this shale division are sandy, fossiliferous cherts holding practically the same fauna as the more typical clayey layers above. The main portion of the shale, however, is as described frequently by Safford, a light blue to green fossiliferous clayey fetid shale. Bryozoa form the most abundant fossils of this shale, but none of them has been named. The ostracods likewise are unnamed, with one exception, *Ctenobolbina loculata* Ulrich, which is known also from the yellow clay beds at the base of the Louisiana limestone in Missouri. The other classes of fossils were studied by Winchell, who recognized among them numerous Kinderhook species. His list of species, published in the "Geology of Tennessee" (pp. 441–446), follows:

Spirifera hirta ? White and Whitfield.
Rhynchonella sageriana Winchell.
Chonetes multicosta Winchell.
Chonetes pulchella ? Winchell.
Producta concentrica Hall.
Chonetes fischeri Norwood and Pratten.
Zaphrentis ida ? Winchell.
Conularia byblis White.
Leda bellistriata ? Stevens.
Solen scalpriformis Winchell.
Discina saffordi Winchell.
Pleurotomaria hickmanensis Winchell.
Phillipsia tennesseensis Winchell.

[1] Safford's Geology of Tennessee, 1869, pp. 442–446.

In another publication Winchell refers to these Kinderhook shale beds as the Hickman shale, but the term was never defined and has since been employed for a formation of Eocene age.

The arenaceous shales and porous cherts forming a band two feet or less in thickness in the upper part of the Ridgetop shale are abundantly fossiliferous and contain species which, considered alone, would be regarded as indubitably Devonian. Among these are a *Striatopora,* and a *Michelinia* of Devonian affinities, but the presence of well-developed species of *Palaeacis, Productus,* and *Agaricocrinus* is sufficient evidence for the post-Devonian age of the fauna.

The Fort Payne chert and St. Louis limestone following the Ridgetop shale in this section are typical for Tennessee, and need no further description than that given in the section.

WHITES CREEK SPRINGS SECTION.

This is undoubtedly the most interesting and important Waverlyan section of Tennessee, first, because it affords a clue to the unsettled points in the stratigraphy of the Central Basin, and second on account of the rather numerous fossils afforded by these rocks, which, in most other localities contain few specimens. The section also throws a somewhat unexpected light upon the equivalence of the different beds of the Waverlyan with those of the upper Mississippi Valley. The Springs emerge from the base of the Chattanooga shale and obtain their chalybeate and other properties from the shale and its contained minerals. Excellent exposures showing practically every inch of the formations listed are to be seen in the road northward to the top of the hill or on the ridge to the east.

Geologic section, Whites Creek Springs, 12 miles north of Nashville, Tennessee.

	Feet.
Waverlyan:	
Fort Payne chert—	
Massive dark gray siliceous and argillaceous limestone weathering into light yellow to brown platy chert. Fossils as a rule uncommon, crinoidal remains being most often observed. *Agaricocrinus americanus*, *A. nodulosus*, *Dorycrinus gouldi*, and *Lobocrinus nashvillae* are the most abundant crinoids	100±
New Providence formation—	
Coarsely crystalline white to gray crinoidal limestone in layers 12 to 18 inches thick, separated by thin green to blue shale bands. Upon weathering these limestones and shales break up, forming glades covered with crinoidal remains	35
Ridgetop shale—	
Light blue to green fossiliferous clay shales, with bryozoans and ostracods most abundant fossils	40
Layers of decomposed chert	0–1
Maury green shale—	
Green shales containing phosphatic concretions	6 in. ±
Chattanooga shale—	
Black bituminous fissile shale	35
Hardin sandstone member	0–2 in.
Silurian limestone.	

In this section the Hardin sandstone, Chattanooga shale, and Maury green shale present their usual characters, differing only in thickness from the same strata elsewhere. The Ridgetop shale has decreased in thickness, although the bed of decomposed, sandy chert is still present at its base. The Kinderhook fauna described under the Ridgetop section is present here throughout this shale.

Succeeding the Ridgetop shale, instead of the usual siliceous limestone of the Fort Payne is a formation of a coarsely crystalline, rather massive crinoidal limestone, with bands of green and blue shale. Both the shale and limestone are highly fossiliferous. Frequently the crinoidal fragments and other fossils are loosely cemented together by a greenish shale, which, upon weathering, leaves the ground strewn with an abundance of specimens. The lithology and general method of preservation is exactly the same as in the Knobstone of Indiana and Kentucky, except that in Tennessee the limestone predominates, while in the more northern areas the shale is much more conspicuous. The fossils likewise are identical so far as they have been collected and identified. Among the bryozoans, *Rhombopora incrassata* Ulrich, the most abundant and characteristic bryozoan of the Knobstone, or, as it should now be called, the New Providence shales, is likewise very common here. *Fenestella regalis*, *Cystodictya pustulosa*, and *Ptilopora cylindracea* of Ulrich, and other bryozoans known from the Knobstone, are also present. The brachiopod *Rhipidomella michelinia* L'Eveille, and *Chonetes illinoisensis* Norwood and Pratten, are as abundant as in the Kentucky strata. The fauna, including the echinoderms which Mr. Springer has identified specifically, is as follows:

Fauna of the New Providence formation, Whites Creek Springs, Tenn.

Favosites valmeyerensis Weller.
Beaumontia americana Weller.
Zaphrentis cliffordana Edwards and Haime.
Amplexus rugosus Weller.
Amplexus brevis Weller.
Cladoconus americana Weller.
Monilopora crassa (McCoy).
Rhipidomella michelinia L'Eveille.
Chonetes illinoisensis Worthen.
Spirifer vernonensis Swallow.
Lasiocladia hindei Ulrich.
Rhombopora incrassata Ulrich.
Cystodictya pustulosa Ulrich.
Fenestella regalis Ulrich.
Ptilopora cylindracea Ulrich.
Metichthyocrinus tiaraeformis (Troost).
Barycrinus cornutus (Owen and Shumard).

Catillocrinus tennesseensis Troost.
Halysiocrinus perplexus (Shumard).
Synbathocrinus robustus Shumard.
Schizoblastus decussatus (Shumard).

Practically every one of the above species has been found in the New Providence shales in the Ohio Valley near Louisville. Mr. Springer's notes indicate many more echinoderms which are common to these Kentucky shales and the Whites Creek Springs bed immediately under discussion. A more complete study of the other fossils will no doubt greatly increase the number of identical species. It therefore seems to me that the equivalence of the New Providence shale and the Tennessee strata under consideration can not be doubted. Not only are the faunas practically identical, but, as mentioned above, the lithological characters of the beds in the two areas are essentially similar. As these Tennessee strata are undoubtedly only the southern extension of the New Providence (Knobstone) shale, it seems desirable to use the same name for them in preference to coining a new term.

The Fort Payne chert in the Whites Creek Springs section differs but little from the beds elsewhere recognized in Tennessee under the names Fort Payne and Tullahoma. For reasons stated before, the latter name is discarded in favor of the former. Fossils, with the exception of crinoids, are extremely rare and the crinoids are by no means common. All of the crinoids from this horizon are of undoubted Keokuk forms, as evidenced by Mr. Springer's list which follows:

Crinoids of the Fort Payne chert, Whites Creek Springs, Tenn.

Agaricocrinus americanus Roemer.
Agaricocrinus nodulosus Meek and Worthen.
Lobocrinus nashvillae Hall.
Alloprosallocrinus conicus Casseday and Lyon.
Eretmocrinus ramulosus (Hall).
Eretmocrinus praegravis Miller.
Dorycrinus gouldi (Hall).

The hills in the vicinity of Whites Creek Springs do not rise high enough to show the St. Louis limestone.

EMBAYMENT DEVELOPMENT OF NEW PROVIDENCE FORMATION IN TENNESSEE.

Sections with the same stratigraphic units as at Whites Creek, and each developed to practically the same thickness, are exposed in the creek valleys just east and west of Whites Creek; but farther away, say 8 or 10 miles west and southwest along the line of outcrops, the New Providence shale division is entirely absent, having pinched out in the intervening space. Going east and northeast from Whites Creek toward Ridgetop, the same thing happens. At Union Hill, 4 miles east of the Whites Creek section, the New Providence division and the Fort Payne chert are both splendidly exposed, but the former is here much reduced in thickness. A few miles farther east the New Providence disappears entirely, as shown in the Ridgetop section. The Whites Creek area, therefore, seems to have been the site of an embayment of the Nashville Island in New Providence times. Considering the location of the area and the lithologic and faunal similarity of these deposits to those of the same age in the vicinity of Louisville, Kentucky, it seems probable that the latter were laid down in the northern part and those at Whites Creek near the southern end of a trough paralleling the Cincinnati axis. So far as known, the New Providence did not extend to the east of this axis. Similar embayments of Richmond and Niagaran times have been described by Hayes and Ulrich.[1] One of their embayments terminates in the northeastern corner of the Columbia sheet, and it is possible that detailed mapping will show the New Providence formation of the Whites Creek area, which is less than 25 miles to the north, to have been deposited in a continuation of the same trough. If true, we have a good example of the permanence of these embayments. The extent of the submergence of this trough varied at least in Richmond and Niagaran times, for the older deposits stretched some miles farther south than did the Niagaran invasion. From evidence here presented and elsewhere in hand it appears that deposition was still more restricted in Waverlyan transgressions. Thus, with each transgression the extent of each subsequent invasion was progressively less, until, in New Providence time, the submerged area extended only a few miles south of Whites Creek Springs. As brought out by Hayes and Ulrich, even the Chattanooga shows evidence of earlier deposition confined to these embayments, with the later Chattanooga spreading far and wide over their borders. Following this New Providence time of greatest restriction, at least of these embayments, the long and general submergence of the Fort Payne sets in, doubtless covering the whole dome.

The development of these shales and limestones in the Whites Creek area has a noticeable effect upon the present topography. In areas where the siliceous Fort Payne rests upon the soft Ridgetop shale or upon the Chattanooga shale, the descent from the Highland rim to the Central Basin is usually very steep. The intercalation of a loosely cemented fragmental, fossiliferous limestone in the Whites Creek area causes a bench to be developed in this otherwise steep descent, so that from a study of the topography one is almost able to determine the outline of the area containing the New Providence.

[1] Columbia Folio, U. S. Geol. Surv., Folio No. 95, 1903.

Proceeding south along the west side of the Nashville dome, the Fort Payne chert rests either upon the Ridgetop shale or upon some lower formation. I am aware of no instance in which the New Providence formation forms a part of the section. However, it is possible that more field work will show deposits in embayments similar to the one at Whites Creek, along the west and south sides of the dome. Safford mentions crinoidal limestone in the lower part of his Siliceous Group at several localities in addition to Whites Creek, and these possibly may prove to be of New Providence age.

CORRELATION.

In the accompanying correlation table I have endeavored to arrange the Waverlyan and early Tennesseean formations according to the available facts. As Schuchert, in his "Paleogeography of North America."[1] has presented a more comprehensive table covering the Waverlyan, or, as he terms it, the Mississippic, I need only call attention to the points in which my own table differs. In the column devoted to the general time units it will be noted that the Kinderhookian does not include the early Waverlyan black shales, and that these are placed as a part of an unnamed series. The Kinderhook never did include these shales, and it would be an unwarranted extension of the series term to make it embrace them. Moreover, these black shales represent a definite time period of pre-Kinderhookian and post-Devonian age, and distinct diastrophic history. In the same column the Glen Park is placed, not below, but above the Louisiana, a position which I determined some years ago in sections at Hamburg, Illinois. The placing of the New Providence under the Burlington at the base of the Osagian is a provisional arrangement, since the close relations to the Lower Burlington are appreciated, and the possibility of their partial equivalence is recognized. A correlation which is made, however, without reserve, is the exact equivalence of the New Providence and the Fern Glen formations. Weller, in his Kinderhook Faunal Studies[2] writes as follows:

> Although our knowledge of this basal Knobstone fauna is incomplete, the evidence available seems to indicate that a reasonably close correlation between it and the Fern Glen fauna can be made.

Mr. Springer's study of the echinoderms strengthens this view, and the occurrence of numerous other Fern Glen fossils in the Tennessee strata here termed New Providence, is thought to establish the correctness of this correlation. The reasons for the adoption and correlation of the other formational names under discussion have been stated in the preceding remarks.

[1] Bull. Geol. Soc. Amer., vol. 20, 1910, p. 548.

[2] The Fauna of the Fern Glen Formation, Bull. Geol. Soc. America, vol. 20, 1909, pp. 265–332.

Correlation table of Waverlyan and early Tennesseean formations.

	Series.	General time units.	Ohio Basin east of Cincinnati axis.	East Tennessee.	North Tennessee.	West side of Nashville dome.	Ohio Basin (Indiana and Kentucky).	Mississippi Valley South of St. Louis.
Tennesseean.	Meramecian.	St. Louis. Spergen. Warsaw.	(Undifferentiated formations.)	Bangor (lower part).	St. Louis. Warsaw.	St. Louis. Warsaw.	St. Louis (Mitchell in part). Spergen. ?	St. Louis. Spergen. Warsaw.
Waverlyan.	Osagian.	Keokuk. Upper Burlington. Lower Burlington. New Providence.	Logan. Black Hand. Cuyahoga (Upper).	Fort Payne.	Fort Payne (Tullahoma). New Providence.	Fort Payne (Tullahoma).	Harrodsburg. Riverside. New Providence.	Boone. Fern Glen.
	Kinderhookian.	Chouteau. Hannibal. Glen Park. Louisiana.	Cuyahoga (Middle). Cuyahoga (Lower).		Ridgetop.	Ridgetop.	Rockford.	Bushberg. Glen Park.
		Chattanooga.	Sunbury. Berea. Bedford. Cleveland.	Chattanooga.	Chattanooga: Maury member. Black shale member. Hardin member.	Chattanooga: Maury member. Black shale member. Hardin member.	New Albany (part).	Chattanooga.

CONCLUSIONS.

To sum up, it is believed that the paleontologic and stratigraphic data presented in the preceding pages warrant the following conclusions:

I. The Waverlyan section in Tennessee, in its most complete development, contains formations of the three series of the general time scale, comprising (1) the Chattanooga black shale with its initial deposit, the Hardin sandstone, and a succeeding green shale with phosphatic nodules, the Maury green shale; (2) an overlying shale here named the Ridgetop, which is referred to the lower part of the Kinderhook; and (3) the Osage formations consisting of (*a*) crinoidal limestone and intercalated green shales equivalent to the New Providence shale of Kentucky and the Fern Glen of Missouri, and (*b*) the Fort Payne chert, a light blue siliceous limestone of Keokuk age.

II. The Chattanooga black shale is a wide-spread, overlapping formation on both sides of the Nashville dome. The Kinderhook Ridgetop shale is apparently restricted to the northern and western flanks of the dome, where, however, it is well developed and usually present in sections. The New Providence has a more local distribution, in fact, it seems to occupy old embayments of the dome. Finally the Fort Payne chert has as great a distribution as the Chattanooga shale.

III. Instead of a single fauna of Keokuk age, two distinct faunas can now be recognized in the classic Whites Creek Springs crinoid locality. One of these, the lower fauna, is identical with that of the New Providence shale, while the other contains only Keokuk species.

IV. The upper Cuyahoga shale, New Providence shale, and the formation in Tennessee here referred to the latter, and the typical Fern Glen of Missouri, contain essentially the same fauna, which, on account of its intimate relation to the fauna of the lower Burlington, causes the reference of these deposits to the Osage instead of the Kinderhook. The stratigraphic relations of the New Providence to the preceding Kinderhook formations are also much less conformable than to the succeeding typical Burlington limestone. There is thus a good diastrophic reason for regarding it as the basal member of the Osage and not as the top of the Kinderhook.